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Comment on amt-2020-492

Anonymous Referee #2

Referee comment on "Evaluation of UV–visible MAX-DOAS aerosol profiling products by comparison with ceilometer, sun photometer, and in situ observations in Vienna, Austria" by Stefan F. Schreier et al., Atmos. Meas. Tech. Discuss., https://doi.org/10.5194/amt-2020-492-RC2, 2021

General Comments

The manuscript entitled "Evaluation of UV-visible MAX-DOAS aerosol profiling products by comparison with ceilometer, sun photometer, and in situ observations in Vienna, Austria" by Schreier et al. presents vertical profiles of aerosols retrieved from Multi-Axis DOAS. The MAX- DOAS observations are compared to co-located measurements of particulate matter, AOD from sun photometer, and backscatter profiles from a ceilometer.

Aerosols play a crucial role in the atmospheric system. They affect air quality, have an impact on radiative transfer, and provide surface areas for chemical reactions. Aerosol vertical profiles from MAX-DOAS provide a valuable contribution to the understanding of the role of aerosols in the boundary layer. Therefore, this manuscript fits well into the scope of AMT.

In general, the manuscript is well written. However, some aspects of the methodology are unclear and important information is missing. In particular, the discussion mainly focuses on regression coefficients between MAX-DOAS and co-located data, but it is not always clear which quantities are actually compared in the regression analysis (see Specific Comments). While regression coefficients provide information only on the precision of the measurements, there could be more emphasis on the discussion of slope and intercept of the linear regression analysis in order to assess the overall accuracy.

Smaller correlation coefficients between surface extinction/AOD from MAX-DOAS and co-located instruments are found during summer. The authors conclude that this is due to a poorer performance of MAX-DOAS during this season. I cannot really see any reason for this. Are the DSCD errors higher or is the information content lower in summer (this would require a discussion of the averaging kernels, see my comment below)? When looking at

the right panels of Fig. 2 and 3, the smaller correlation coefficients instead seem to be caused by aerosols being less abundant during summer than in other seasons, leading to poor statistics. Furthermore, there is a single outlier in the Vis data (lower-right panel of Fig. 3) that is likely to have a strong impact on the slope of the regression line.

Apart from some general remarks on the vertical range of the retrieved profiles, a discussion on the vertical sensitivity based on averaging kernels is missing. At least some examples of averaging kernels for different atmospheric scenarios should be presented and discussed. Due to the limited vertical resolution of the MAX-DOAS extinction profiles, a quantitative comparison between MAX-DOAS and Ceilometer profiles requires the convolution of the high-resolution Ceilometer profiles with the MAX-DOAS averaging kernel according to Rodgers and Connor (2003) (see, e.g., Frieß et al., 2016 and Tirpitz et al., 2021). This is of particular importance because the vertical sensitivity of the aerosol profiles retrieved by the BOREAS algorithm appears to be limited to the lowermost 500 m (Fig. 9 in Bösch et al., 2018), which means that large fractions of the aerosol column are invisible for the MAX-DOAS instrument.

Specific Comments

Abstract L20-23: It is not correct that coincident measurements of temperature and pressure profiles were used here for the first time for profile inversion, see e.g. Friedrich et al. (2019), who used daily radiosondes.

P6, L15: Do you use the 0° elevation measurements for the profile retrieval? I could imagine that this leads to difficulties in the inversion, either due to blocking by surrounding buildings or trees, or due to the fact that the field of view includes both atmosphere and surface.

P8, L12: Mean vertical profiles of which quantities are used as input parameters for the RTM?

I suggest to structure the sub-sections of Section 2.2 in the order of their importance, starting with the MAX-DOAS profile retrieval, and to move Section 2.2.1 on cloud flagging to the end of section 2.2.

P8, L16: It is not clear to me what the term ‘Hence’ refers to. The term ‘Differential slant column’ is not defined yet and should either be explained here, or replaced by ‘measurements’.

P8, L19-24: The technical description of the pyranometer should be moved to section 2.1.

P9, L4: What do you mean with 'daily total second-order difference'? Is this the mean of the second-order differences? Please clarify.

P9, L25: The term 'oxygen dimer' should be avoided; O_4 represents the O_2 collision complex.

P10, L7: Again, this is not the first time that measured atmospheric profiles of pressure and temperature from a co-located site are used for MAX-DOAS profile retrieval, see general comments.

Section 2.2.2: An error discussion regarding the retrieved aerosol profiles is completely missing. Retrieval errors and vertical resolution based on averaging kernels, as well as information content should be discussed here. A discussion of averaging kernels is particular importance because the lack of sensitivity for aerosols at high altitude might explain parts of the discrepancies between MAX-DOAS and ceilometer, and because the ceilometer profiles should be convoluted with the MAX-DOAS averaging kernels in order to perform a quantitative intercomparison between both data sets (see general comments).

P11, L7: In which way has time been extracted from the backscatter profiles? Do you mean the time stamp of the profiles? This would not really be worth mentioning.

P11, L13,19 and 22: I think the term 'assimilation' is inappropriate here because it has a well-defined meaning in atmospheric science, namely to adapt a modelled atmospheric state to observational data in a statistically optimal way. Maybe gridding the data (in time and space) would be a more appropriate term.

P11, L15-19: Please add a sentence motivating why the temporal averaging has been done in such a quite complicated way, instead of just averaging over the duration of a MAX-DOAS scan.

Please describe how you are dealing with the missing aerosol information from the Ceilometer in the lowermost 50 m, where MAX-DOAS is most sensitive and variability in aerosol extinction is probably highest. What kind of extrapolation did you apply for the calculation of the extinction in the lowermost retrieval layer and for the determination of the AOD?

P12, L25: It is not clear what kind of data has been used for the calculation of the correlation coefficients. Did you correlate extinction at all heights, or just at the surface?

Seasonally averaged or individual profiles?

P14, L11: Here it is stated that there is limited sensitivity of MAX-DOAS aerosol profiles above 4 km. When looking at Fig. 9 in Bösch et al. (2018), the sensitivity rather seems to be restricted to the lowermost 500 m only. Again, this means that a convolution of the Ceilometer profiles prior to the comparison is crucial – see general comments.

P16, L3: Here you distinguish between the availability of total columns and surface values. Shouldn't the total column always be available if the surface value is available and vice versa, since both are derived from the according vertical profile?

Technical Corrections

Title of 2.1.4: 'In situ' -> 'In situ aerosol measurements'

P9, L23: Remove 'Briefly' from the beginning of the sentence.

P9, L26: Remove comma after 'thus'.

P12, L8: A threshold in difference between modelled and measured O4 DSCD of 1000 molec^2/cm^5 is extremely small, given that typical O4 DSCDs are in the order of 10^{43} molec^2/cm^5. Is this a typo?

References

Rodgers, C. D. and Connor, B. J.: Intercomparison of remote sounding instruments, J. Geophys. Res, 108(D3), 4116–4229, doi:10.1029/2002JD002299, 2003.